

**The validity and reliability of a wearable accelerometer  
during the bodyweight squat and countermovement jump.**



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**The Faculty of St Mary's University College**

**By**

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## **ABSTRACT**

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The validity and reliability of a wearable accelerometer during the bodyweight squat and countermovement jump.

By

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Master of Science in Strength and Conditioning

The purpose of the study was to verify the reliability and validity of a wearable device for the assessment of peak acceleration (PA) and peak power (PP) during the body weight squat (BS) and counter movement jump (CMJ). Fifty-nine recreationally trained subjects (age =  $37.4 \pm 7.9$  years; body mass  $75.13 \pm 11.99$ kg) performed three trials each on two separate training days of both BS and CMJ. PP and PA were simultaneously quantified using a Kistler force-plate and a wrist wearable device. Compared to the force-plate (FP), the wearable (W) determined significant systematic bias for PA during BS (day 1 =  $2.06 \text{ m/s}^2$ , day 2 =  $3.02 \text{ m/s}^2$ ,  $p < 0.05$ ) and CMJ (day 1 =  $6.14$

m/s<sup>2</sup>, day 2 = 6.35 m/s<sup>2</sup>,  $p < 0.05$ ). Intraclass correlation coefficients (ICC) for PA BS and CMJ (0.73 - 0.80) were “moderate to good”. Bland Altman (BA) revealed no statistical level of agreement for validity of both PA and PP ( $p < 0.05$ ). Reliability ICC for PA W (0.78 - 0.92) and FP (0.81 - 0.83) and PP W (0.93 - 0.90) and FP (0.90 - 0.93) were “good to excellent”. BA only confirmed absolute agreement from FP CMJ PA and CMJ FP and W PP ( $p < 0.05$ ). A significant systematic bias was reported across both devices on day 2 of testing for PA and PP ( $p < 0.05$ ). Findings indicate that the W device is not valid for determining PA and PP compared to that of the gold standard however PA reliability measures should not be discounted.

**Keywords:** force platform, peak acceleration, peak power, athlete testing.

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Please note that Microsoft had no access to the data collected, nor has any funding been provided for this study. The first author of this article has no connection with Microsoft and completed

all testing, data analysis and was the sole contributor to the results and discussion section. The results of this study do not constitute endorsement of the product by the authors or the NSCA.

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# **Chapter I**

# **Chapter I**

## **INTRODUCTION**

In professional strength and conditioning (S&C) training programmes, it is key for both coaches and athletes to have the ability to monitor training loads and intensities. Peak acceleration (PA) and peak power (PP) values during S&C exercises are now recognised as critical metrics for evaluating and improving athlete performance (43, 12, 24). PA has been studied in sports evaluating swimming performance (7), impact severity in boxing (6) and speed skating whilst measuring both linear and rotational accelerations of helmets (26) and during both flight time and take off of the counter movement jump (CMJ) (36). PP has been commonly examined in order to enhance performance in Olympic Weightlifting (OWL) exercises (24) the CMJ (33) and also throughout upper limb exercises such as bench throws (15).

Acceleration research was first published in 2000, providing analysis on the speed of execution of various phases of the snatch in OWL (20). The findings of this research allowed coaches to observe the tri-axial linear kinematics from two VHS cameras that assessed the change of energy in the barbell. This ensured athletes could be coached specifically on phases of the lift that speed of execution was reduced, allowing for the enhancement in performance over time. Acceleration data can also be used to estimate force and power via the differentiation of acceleration and mass data (13) and has been proven to produce reliable outcomes on assessing muscular power (45). This provides coaches with an increased understanding of the performance capacity of their athletes, adding significant value to training and testing. Some more recent studies have looked at patterns of barbell acceleration during the snatch (27) and acceleration and deceleration patterns in soccer-specific movements (41) utilising video analysis and inertial measuring

units. Linear position transducers (LPT) have also been commonly used to measure both peak and average force. Variables have been collected while assessing jump performance of the squat, CMJ, and drop jump (DJ) (44), back squat and bench press (11, 16), hang power clean (HPC) and the weighted jump squat (24). In addition to this, LPT has been used to assess loaded jump squats among elite rugby players to determine peak force (22). As a result, the LPT is regarded as a valuable tool that has displayed some consistently accurate data. The application of wearables for this type of testing is still largely untested, though they could prove a less complex, less costly and more portable training tool than previously used methods.

The gold standard device for measurement of acceleration (13) and for direct performance outcomes (32) is still regarded as the Kistler force-plate (FP). The LPT has been

compared to the gold standard in research, returning consistently accurate data in tests and is therefore considered a valid alternative to FP (14). Other measuring and monitoring tools such as video analysis though have not always been validity tested against the gold standard and their reliability and the validity of the data collected cannot be assumed. Limited studies into the use of wearable accelerometers have begun to emerge over the last five years, though not all have been validated against the gold standard (11). Some examples of the objective measures now being routinely taken using wearables include heart rate, sleep performance and acceleration (21). As wearables such as the Microsoft Software Development Kit 2 (SDK2) are introduced into the S&C coaching toolkit as affordable and portable measuring devices, it is important these are compared to the gold standard before being accepted in the field as a valid alternative to FP, or other tools, in the measurement of PP and PA.

Vertical jump performance has been assessed and used in some of the earlier studies into the use of wearables (10). Although the results of this research confirmed the reliability and validity of an accelerometric system in displaying high levels of reliability for assessing jumping height, leg stiffness, reactivity index and velocity and power during the jump squat, the force and power measurements were only deemed as partially valid. Despite this, the study concluded that the accelerometric system was still reliable to use when assessing the studied variables. This research is promising for S&C coaches and athletes as to how wearables may reliably be applied in the field.

Accelerometers have also been studied in measuring average acceleration values during high speed running over a 40m distance (2). To provide a concurrent measure of acceleration, timing gates were positioned at 10m intervals from

0-40m. The wearable data significantly overestimated average acceleration values and therefore questioned its effectiveness in providing accurate data. The study concluded that body mass and the absence of a gravity compensation formula affect the accuracy and practicality of accelerometers and that until GPS sports integrated accelerometers integrate a gravity compensation formula, the usefulness of any accelerometer derived algorithms is questionable.

Recent research has been carried out to validate a wireless wearable device as compared to a wired motion capture system as a means of measuring velocity during basic, single-joint resistance exercises (37). The team concluded that the wireless device could potentially replace currently used, wired devices as a user-friendly, accessible method to measure velocity in a wide range of resistance exercises. The study was conducted on single-joint movements only and was not compared to gold standard, therefore limited conclusions can be

drawn as to its effectiveness in more complex, multi-joint resistance exercises as measured by a FP.

In late 2013, a new wearable device was launched in Toronto that was devised to measure velocity and power and key indicators of athletic performance. One of the first studies to confirm reliability of the new 'PUSH' wearable was published in 2016 where observations of peak movement velocity during the back squat were made against the T-Force LPT. Thus resulting in high correlations being seen in both mean and peak velocity (3). Although systematic bias was observed between devices, wearable devices could have valuable applications for S&C coaches. The speed at which an athlete can lift or move can provide detail on how appropriate the load is, measure athletes levels of fatigue and allow focused targets for some key principles of training such as strength, power, endurance and speed. A further study has recently reported its findings on the use of a wearable accelerometer known as the Gyko inertial

sensor system in verifying validity for the assessment of vertical jump height (28). Comparisons were made against the gold standard kistler force plate as well as the Optojump photoelectric cell system. The results suggest that in order to estimate true vertical jump height for the Kistler force plate and Optojump device from the Gyko derived data, that specific regression equations are required therefore, questioning its concurrent validity.

Due to the relatively limited body of literature available and their inconclusive findings, wearable monitors require further investigation before they can be recommended for use in the field. The aim of the current study is to test the reliability and validity of a wearable device (the Microsoft SDK2) and compare the PA and PP values to that of the gold standard portable 3-dimensional Kistler FP, using values elicited from the full movement of both the BS and CMJ. This research will follow best practice for validation of wearable monitors (5) in

measuring PA and PP in two established, functional, multi-joint exercises. Data will be collected and examined during a slow, more strength-based exercise and a faster, more powerful exercise. The back squat (BS) is one of the most fundamental exercises in S&C training and is used in a plethora of sports and by many athletes. It replicates the functional movements of our day-to-day motor patterns and it is often programmed within the basic strength phases of training plans and has been commonly used within reliability and validity studies (11, 16). The countermovement jump (CMJ) has been used less within reliability and validity studies (14, 18), though on both of these occasions the results showed strong concurrent validity and excellent test re-test data.

Based on the findings of previous research, it is hypothesised that in this study there will be a strong positive relationship between the PA and PP data extracted from the wearable to that of the derived PA and PP data from the FP,

thereby confirming the device validity. Furthermore, it is predicted that by using the force time curve and extracting data variables from the full movement, a significant positive relationship between tests will confirm reliability.

## **Chapter II**

## **Chapter II**

### **METHODS**

#### *Experimental Approach to the Problem*

The aim of this study was to test the reliability and validity of a commercially available wearable device (W) to measure acceleration. Both PA and PP values were assessed simultaneously between days (1 v 2) and comparisons were made between devices (W v FP) in order to confirm reliability and validity. The BS and CMJ exercises were chosen as they are commonly used in both strength and power training programmes (46). Therefore, any statistically proven research that has the ability to enhance the performance of these exercises would be valuable for both coach and athlete. No study has yet determined the validity of a wrist wearable accelerometer in measuring PA and PP during the BS and CMJ. All 59 recreationally trained subjects that complete 3-5 mixed training

sessions, equating to a total of 4-6 hours a week of varied training time (comprising of cross fit, general weight training and Olympic lifting), were recruited to perform 3 x bodyweight BS and 3 x bodyweight CMJ on 2 separate occasions. Testing sessions took place over a 7-day period with each subject ensuring 24 hours rest had occurred between sessions. Each repetition was simultaneously measured using the FP whilst the wearable device was worn on the left wrist. The measuring tool on the wearable device was placed on the distal aspect of the forearm on each subject in order to ensure consistency across testing of all participants.

### *Subjects*

Each subject was issued with an information sheet detailing the risks of participation and their right of withdrawal at any stage within the study. They each signed a university consent form and PARQ and were free from injury throughout testing. The

ethical board of St Mary's University approved the experimental process for the use of human subjects. Of the 59 subjects that volunteered to take part in the study, 42 were male and 17 were female.

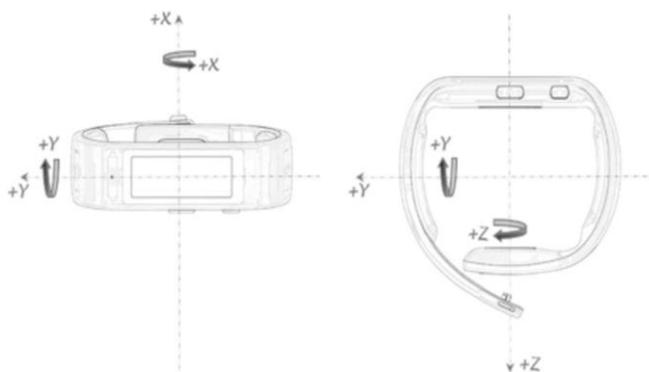
### *Instrumentation*

The Microsoft SDK2 Band 2 seen in Figure 1 was used to collect acceleration data.



**Figure 1.** Microsoft Wearable SDK2 (.TIFF format).

The band weighs 61g (grams), measures at a frequency of 62Hz (hertz) and measures acceleration in units of g (9.81 m/s). It contains a gyrometer with 3 axes (vertical, antero-posterior, medio-lateral) allowing for acceleration data to be obtained from 3 planes as shown in Figure 2.



**Figure 2.** Accelerometer and gyroscope axes orientation.

(.TIFF format).

The data was extracted and gathered using a Universal Windows 10 application running on a Microsoft Lumia 950 device. When

the testing coordinator chose to start recording (pressing a button in the app) the phone opened a Bluetooth connection to the Microsoft Band worn by the participant. The participant then performed the repetition whilst wearing the band and standing on the FP. The testing coordinator used the app to start the rest period at the end of the repetition, which initiated a countdown timer to be displayed on screen. During the repetition the acceleration readings were sent live via Bluetooth from the wearable to the phone. This data was then recorded in a list by the app and once each repetition was complete, saved to a .csv file. One file was saved per rep and per exercise. On completion of each participant's repetitions, the phone was plugged into a PC and the .csv files were copied across to the computer for analysis. The portable Kistler FP (model 9286A; range 0-10kN; dimensions 600mm x 400m; sampling rate 1000Hz, Kistler Instruments Ltd, Hampshire, UK) was positioned in the centre of the gymnasium hall and calibrated at the start of each

repetition. The FP was connected to a stand-alone computer via the Kistler control unit (model 5233A2) and the proprietary software Bioware (version 5.1.3.0) was used to calculate force time data per repetition.

### *Procedures*

The test was performed within a secured gymnasium hall and no access was authorised throughout testing in order to minimise any noise and distractions, which could affect the accuracy of the data collected. Before each testing session, all subjects were instructed to refrain from strenuous activity for at least 48 hours. On arrival, a 10-minute structured warm up was provided to all subjects with strict instructions to ensure that the effort level perceived remained at 5/10 on the Borg Scale. The warm up included a 5-minute stationary cycle followed by 10-15 repetitions of 9 active stretches that included both open and closed gate exercises; walking hamstrings, calf bounds, sumo

squats with adductor squeeze, walking quadriceps stretches, and A lines both left and right. Testing occurred on completion of the full warm up and after a demonstration of both BS and CMJ, by the testing coordinator. This was easily achieved as subjects attended booked slots in waves of 15 minutes. Both exercises commenced in the standing position and each subject was instructed to remain stationary for approximately 3-5 seconds prior to starting the movement in order for body weight data to be calculated from the FP. The BS was performed with feet positioned shoulder width apart and arms crossed over the chest and the CMJ was performed with hands placed on the hips. Each repetition was completed at the subjects' own pace and to a self-selected depth through-out both exercises (31). No verbal constraints were issued regarding technique, depth of the squat or jump height. Exercises were performed as part of a randomised crossover design, with half of the subjects starting by executing the BS followed by CMJ and the other half starting

with the CMJ followed by the BS. On day 2 of testing this was reversed. A 60 second interval between repetitions provided a rest to the subject and afforded time to re calibrate the FP. The application on the phone provided the consistent countdown timer, allowing for 3 minutes between exercise types.

Data was extracted from both the W and FP simultaneously during the complete movement of each repetition. Both sets of data from each device were uploaded into Microsoft Excel where the variables were calculated according to either the direct force from the FP via the ground reaction force (GRF), or acceleration magnitude from the wearable in units of gravity (g). FP data for all repetitions and the vertical component of GRF was used in conjunction with body mass of each subject to determine instantaneous acceleration. Vertical velocity of centre of gravity (CG) was then calculated by instantaneous acceleration multiplied by the

time interval of 0.001. Instantaneous power was then calculated as follows:

$$\text{Power (W)} = \text{vertical GRF (N)} \times \text{vertical velocity of CG (m.s}^{-1}\text{)}.$$

Wearable data for all repetitions and the acceleration magnitude (g) ( $1G = 9.81 \text{ m/s}^2$ ) was multiplied by 9.81 to convert to units of  $\text{m/s}^2$ . It was then multiplied by the combined mass of each subject to determine instantaneous force as follows:

$$\text{Force (N)} = (\text{body mass (kg)} \times \text{acceleration magnitude (m/s}^2\text{)}).$$

Velocity was calculated by the acceleration multiplied by the time interval of 0.016 and power was calculated as per the FP. The data was extracted by observing the force and acceleration magnitude time curves of the full movement of both exercises. Once the data was plotted, formulas were inputted

into excel that allowed for the extraction of the data throughout both concentric and eccentric movements of each repetition. Data was extracted when force and acceleration magnitude changed from constant body weight to deceleration (downward movement). The completion of data extraction was at the point where movement returned to the starting position where GRF returned to body weight and acceleration had returned to the starting constant position. From this extraction of data, both PA and PP values were obtained per repetition and per exercise.

### *Statistical Analysis*

All statistical analyses were conducted using Statistical Package for the Social Sciences software (SPSS, v22.0). PA and PP were calculated from each of the 3 repetitions, per exercise (Squat v CMJ) and per day (1 v 2) and were cross-compared to that of the same rep and exercise across both devices. A Shapiro-Wilk test was conducted in order to determine data normality and in the

presence of a level of agreement, a linear regression was conducted in order to confirm any existence of proportional bias. Test re-test reliability and validity was assessed using intraclass correlation coefficient (ICC) (relative reliability) in order to describe how strongly tests-means and equipment-means resembled each other. An ICC of  $r = 0.29 - 0.79$ , indicates weak to moderate,  $r = 0.80$ , indicates good agreement and a value  $r = 0.90$ , indicates excellent agreement (4). Bland Altman (1983) (absolute reliability), were conducted to determine systematic bias and random errors, along with lower and upper limits of agreement (LoA), in order to determine whether the two measurement means were statistically significant from one another and do not display a level of agreement. A statistical level of significance was considered at ( $p < 0.05$ ).

## **Chapter III**

## Chapter III

### RESULTS

The mean, SD and coefficients of variation per trial and per exercise are presented in table 1.

**TABLE 1.** Mean and ( $\pm$  SD) with CV% values of test and retest reliability for peak acceleration ( $\text{m/s}^2$ ) and peak power (w) measured with FP and W.

		Wearable		Force Plate	
		Mean $\pm$ SD	CV%	Mean $\pm$ SD	CV%
Squat	Day 1	15.32 $\pm$ 2.64	17	13.24 $\pm$ 1.71	12
Squat	Day 2	*17.35 $\pm$ 3.91	22	*14.32 $\pm$ 2.41	16
CMJ	Day 1	43.83 $\pm$ 12.41	28	37.97 $\pm$ 14.27	37
CMJ	Day 2	*46.52 $\pm$ 12.59	27	*40.14 $\pm$ 13.20	32
		Mean $\pm$ SD	CV%	Mean $\pm$ SD	CV%
Squat	Day 1	446.93 $\pm$ 338.76	75	1020.59 $\pm$ 385.79	37
Squat	Day 2	*519.92 $\pm$ 345.11	66	*1197.70 $\pm$ 508.21	42
CMJ	Day 1	2570.07 $\pm$ 1488.780	57	119.90 $\pm$ 81.83	68
CMJ	Day 2	*2839.20 $\pm$ 1649.01	58	*135.89 $\pm$ 95.11	69

\* Variables displaying systematic bias (seen on day 2 of all tests between tests  $p < 0.005$ ).

A Shapiro-Wilk test ( $p > 0.05$ ) and a visual inspection of their histograms showed that the following variables were normally distributed; BS day 1 FP PP with a skewness of 0.51 (0.31) and kurtosis of 0.42 (0.61), CMJ W day 1 PA with a skewness of 0.93 (0.31) and a kurtosis of 1.93 (0.61) and CMJ W day 2 PA with a skewness of 0.56 (0.31) and a kurtosis of 0.38 (0.61). All other reliability and validity PA and PP variables extracted from both W and FP were statistically significantly different from a normal distribution. They were not normally distributed and these can be seen in Table 2.

**TABLE 2.** Results of Shapiro-Wilk test of normality for peak acceleration ( $m/s^2$ ) and peak power (w) across all variables ( $p > 0.05$ ).

Exercise	Equipment	Day	Peak Acceleration			Peak Power				
			Skewness	SE	Kurtosis	SE	Skewness	SE	Kurtosis	SE
Squat	Wearable	1	1.53*	0.3	3.75	0.6	1.51*	0.3	0.95	0.6
		2	1.48*	0.3	3.39	0.6	1.25*	0.3	0.44	0.6
CMJ	Wearable	1	0.93	0.3	1.93	0.6	1.36*	0.3	3.1	0.6
		2	0.56	0.3	0.38	0.6	1.01*	0.3	0.33	0.6
Squat	FP	1	1.51*	0.3	3.91	0.6	0.51	0.3	0.42	0.6
		2	1.59*	0.3	4.27	0.6	0.85*	0.3	0.12	0.6
CMJ	FP	1	1.32*	0.3	2.31	0.6	1.59*	0.3	2.37	0.6
		2	1.35*	0.3	2.57	0.6	1.59*	0.3	2.36	0.6

\* Significant P values  $p > 0.05$

Compared to the FP the W device determined significant systematic bias for PA during BS day 1 and day 2 and CMJ day 1 and day 2. ICC reported “moderate - good” validity between W and FP for PA for both the BS (0.74 – 0.75) and CMJ (0.73 – 0.80) across days 1 v 2 as seen in Table 3. PP validity between W and FP was poor, revealing no relative reliability in the validity between devices (0.04 – 0.28). Bland Altman (BA)

revealed no statistical absolute level of agreement for validity of both PA and PP ( $p < 0.05$ ).

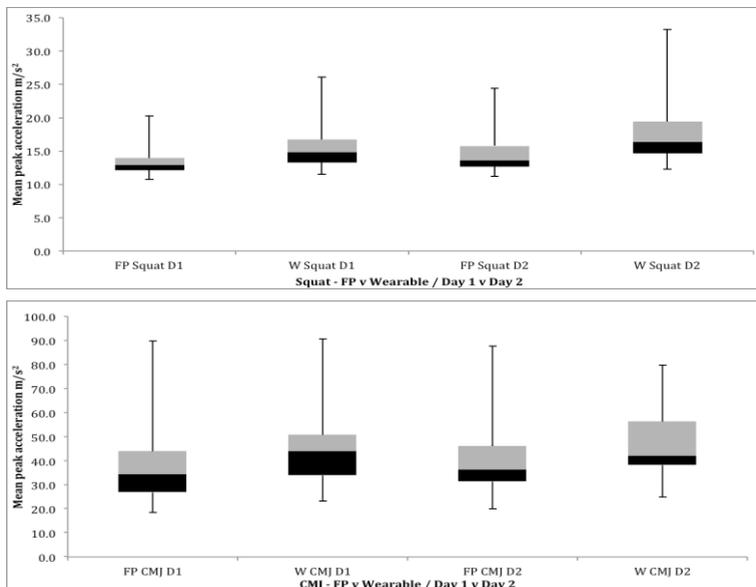
**TABLE 3.** Validity of PA between devices, ICC and 95% Upper and Lower Bound LOA:  $n = 59$ .

Validity		Wearable v Force Plate		
		90% Confidence Intervals		
Peak Acceleration	ICC	Lower Bound	Upper Bound	Wearable Systematic Bias
Squat 1	0.75	-0.18	0.92	2.06
Squat 2	0.74	-0.19	0.92	3.02
CMJ 1	0.73	0.47	0.85	6.14
CMJ 2	0.8	0.47	0.9	6.35

ICC reported “excellent” reliability between test days for W PP (0.90 – 0.93) and good reliability for FP PP (0.88). PA ICC were also reported as “good to excellent” for the W (0.78 – 0.92) and FP (0.81 – 0.83). A significant systematic bias was reported across both devices on day 2 of testing revealing the following outcomes; PA BS W ( $2.05 \text{ m/s}^2$ ,  $p < 0.05$ ), CMJ W ( $2.66 \text{ m/s}^2$ ,  $p < 0.05$ ), BS FP ( $1.08 \text{ m/s}^2$ ,  $p < 0.05$ ), CMJ FP ( $2.45 \text{ m/s}^2$ ,  $p <$

0.05). PP BS W (277.77 W,  $p < 0.05$ ), CMJ W (269.123  $\text{m/s}^2$ ,  $p < 0.05$ ), BS FP (177.09 W,  $p < 0.05$ ), CMJ FP (15.99 W,  $p < 0.05$ ). A visual representation can be seen in Figure 3.

**Figure 3.** Mean PA ( $\text{m/s}^2$ ) values between exercises (Squat v CMJ) and (Day 1 v Day 2). Displaying SD either side of the mean to include (minimum, 25<sup>th</sup> percentile, median, 75<sup>th</sup> percentile and max).



Bland Altman revealed no statistical absolute level of agreement between the test re-test values of the PA between BS and CMJ (W) and BS (FP) on day 1 v day 2 ( $p < 0.05$ ). A level of agreement was detected between CMJ (FP)  $t = (59) = (1.846)$ ,  $p = 0.07$  and the results of a linear regression test ( $p > 0.05$ ) revealed no proportional bias  $t = (59) = (1.87)$ ,  $p = 0.67$ .

Peak power reliability revealed no statistical level of agreement between the test re-test for BS (wearable) day 1 v day 2 and BS (FP) ( $p < 0.05$ ). A level of agreement was detected between CMJ (W)  $t = (58) = (2.30)$ ,  $p = 0.025$  with a linear regression test ( $p > 0.05$ ) revealing no proportional bias  $t = (59) = (0.67)$ ,  $p = 0.50$  and CMJ (FP)  $t = (58) = (2.23)$ ,  $p = 0.029$  with a linear regression test ( $p > 0.05$ ) revealing no proportional bias  $t = (59) = (1.13)$ ,  $p = 0.26$ .

## **Chapter IV**

## **Chapter IV**

### **DISCUSSION**

A comparison using these 2 variables measured by a wearable has not been previously reported in the literature. The main findings of the study reported “good” ICCs for PA between devices, suggesting that the W and FP have relative reliability. However, it was determined that the W significantly over estimated values compared to the FP (over estimation of PA,  $p < 0.005$ ) for both BS and CMJ. Our results were in line with others reported in the literature where average acceleration values have been continually over estimated by a tri-axial wearable (integrated within a wearable tracking device) during high speed running ( $p < 0.001$ ) (2), as well as within studies comparing LPT to FP in the measuring of peak power and peak velocity at different loads (16) performing various exercises (25, 42, 1). These studies also confirm that over estimations have commonly been reported among other devices, in this instance

the LPT, in estimating power, although it was suggested that the increase in force output production derived from double differentiation of the bar placement was the main cause of error (16).

Whilst ICC produced promising results for PA validity between devices, Bland Altman analysis revealed that the 2 devices are statistically significantly different from one another and do not display any level of agreement. Therefore, the W cannot be used interchangeably with the Kistler force plate in recreationally trained individuals. This seems to be a common finding with many other inertial sensor systems where ICC's have reported excellent agreements (35) yet systematic bias between devices occurs (28). Picerno et al (34) found excellent agreement ( $ICC = 0.83$ ) during CMJ flight time but revealed significant differences between the devices ( $p < 0.0001$ ) due to jump height being underestimated. Castagna et al (9) also

compared CMJ flight time between the Myotest sensor system, Kistler FP and an Optojump system reporting excellent agreement (ICC = 0.88) but significant systematic bias was reported ( $p < 0.0001$ ) with the Myotest device reporting an average of 7.2% longer flight time compared to the Optojump.

More promising results from the W were displayed between the test re-test of the devices reporting “good to excellent” ICC’s for both PA and PP, although another bias was observed between testing days, with day two of testing seeing an increase in mean values across both W and FP for PA and PP. This could be attributed to lack of familiarity of the task or other peripheral factors such as differences in acceleration magnitude due to the wearables overuse or absence of calibration between trials, although this was not a requirement discussed with Microsoft in order to maintain device accuracy. However, step-by-step procedures were stringently applied across both testing

days ensuring participants followed the structured warm up and adhered to the same testing procedures as day 1 on day 2. This was also consistent with that of other studies methodologies (3,16), thus ensuring that external bias factors were all considered and eliminated. Suggesting that this bias could be due to human error, or indeed a consequence of measuring using a portable device during a complex movement instead of a more basic single joint exercise. Conversely, it is imperative to highlight that the bias was observed across the same testing day, with the same device and was seen in both the FP and W. However, as the exercises were completed simultaneously, this could portray a positive trend in accuracy if both devices were reporting increases in values on the same testing days. A similar study by Choukou (10) used an accelerometric system (Myotest) and FP for assessing vertical jumping performances. The results showed a high level of reliability with no significant differences

between devices ( $p < 0.05$ ), though validity could also not be confirmed.

The limited literature on wearable devices contributes to the difficulty in use of correct methodology in testing, as well as in the development of algorithms to be applied within the data extraction (21,23). Many manufacturers provide these formulas as integral algorithms within the device in order to extract more accurate data (28), however this was not applied in this research and could therefore be considered as a limitation. Other studies (3) have also benefitted from software programmes that automatically calculate specific parts of the movement by detecting the start and the end of the concentric phase with proprietary algorithms. It could be argued that this capability could produce more accurate data, as compared to data extracted from a force time or acceleration time curve by the naked eye. A further limitation of the current research could therefore be due

to the analysis of the data extracted from the whole movement rather than concentric or eccentric components of the BS or take off and landing of the CMJ.

The positioning of the wearable device also warrants discussion due to acceleration in G acting as a constant on the device before any movement occurs. Although this can be accounted for before the final extraction of the movement data analysis by subtracting 9.81m.s, it should also be considered that movement disparity has to play a role in the overall mean of acceleration magnitude. Postural sway into various planes may account for error in the overall reading and therefore could be an additional limitation in the current study due to the exercises not being completed in a fixed plane. A similar validity and reliability research study of the new 'PUSH' wearable analysed movement velocity during the BS exercise, although within a Smith machine thus limiting any increases in antero-posterior

and medio-lateral planes, thereby reducing the possibility of error (3). In order to reduce any errors in the current study the wearable was positioned consistently on the left wrist of every subject and all subjects were thoroughly informed to position their hands according to the exercise type and keep them as still as possible throughout the movement.

The 'PUSH' wearable has the most similarities to that of the Microsoft SDK2 band featured in this study regarding position on the body throughout testing. It is also worn on the upper body yet is attached on the forearm. The sampling rate is higher than the SDK2 (SDK2 = 62Hz, 'PUSH' = 200Hz) and it calculates the mean average velocity of the movement by averaging all instantaneous velocities. The system is linked to the custom 'PUSH' app via Bluetooth connection where load, reps and sets can all be selected as variables and results are obtained instantly. This differs slightly from the SDK2 wearable

as the results are extracted live as it is being measured from the band via the app. The app stores the data on a SD card on the phone and data is copied to the PC for analysis, therefore not providing instant feedback within the training setting. It is clear that the 'PUSH' wearable has been developed specifically for professional use within the S&C industry and the results of the research study confirmed almost equal reliability to a T Force LPT. It must be noted that validation has not yet been confirmed comparing its variables to the gold standard. It appears that wearables that are developed specifically for use as a S&C measuring device are likely to be significantly more accurate.

The performance of the SDK2 wearable warrants further investigation. Having proven relative reliability, this could be considered as a significant enough result to permit use in a recreational setting and could potentially replace currently used wired devices in measuring acceleration i.e. not for professional

use but to mark smaller improvements in performance during single-joint exercises. This would be supported by the findings of the study by Sato (37), examining the 'PUSH' wearable in measuring peak and average velocity data to a motion capture system during basic bicep curl and shoulder press exercises, revealing accurate comparisons to 3D measures. The device could not only support coaches in measuring fatigue due to a reduction in acceleration across a set or load but also across a variety of exercises due to its wireless capabilities. Data can be stored and observed within an application for scrutiny on completion of the training session or provide instant feedback allowing for training adaptations to be made instantly. Notwithstanding the ease of use, transportation and cost effectiveness compared to other devices.

It was hypothesised based on the findings of previous research that there would be a strong positive relationship

between the PA and PP data extracted from the wearable to that of the FP in both reliability and validity. Findings do not support the hypothesis and indicate that the W device cannot be used interchangeably with a FP for determining absolute reliability and validity for PA and PP. We conclude therefore that this device is not useful in the measuring of both PP and PA accuracy compared to that of the gold standard FP and S&C enthusiasts should use this device with caution although should not discount the ICC reliability measures for PA.

## **Chapter V**

## **Chapter V**

### **PRACTICAL APPLICATIONS**

The findings of the present study confirm that the Microsoft SDK2 Band is not a useful tool for the S&C coach to monitor training and performance of recreational athletes, having not proven absolute validity in the measurement of PP and PA. However, we must be mindful that previous studies have confirmed reliability of measuring devices that have displayed similar ICC to what was reported and derived from the SDK2 Band. S&C coaches therefore, should not discount its use in providing basic PA feedback between sessions for younger early developing athletes requiring a measuring device that is low cost, easy to transport and simple to use for basic exercises, which will also provide an additional form of feedback.

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# Appendix A

## Signed Ethics Application



St Mary's  
University  
Twickenham  
London

### Approval Sheet

Name of applicant: Khym France

Name of supervisor: Hayley Legg

Programme of study: Strength and Conditioning MSc

Title of project: The validity and reliability of a wearable accelerometer during the countermovement jump and bodyweight squat.

Supervisors, please complete section 1 or 2. If approved at level 1, please forward a copy of this Approval Sheet to the School Ethics Representative for their records.

#### SECTION 1

Approved at Level 1

Signature of supervisor (for student applications)

#### SECTION 2

Refer to School Ethics Representative for consideration at Level 2 or Level 3

Signature of supervisor.....

Date.....

#### SECTION 3

To be completed by School Ethics Representative

Approved at Level 2

Signature of School Ethics Representative:

07/02/2017

## Appendix B

### Information Sheet



St Mary's  
University  
Twickenham  
London

**Title of project:** The validity and reliability of a wearable accelerometer during the countermovement jump and bodyweight back squat.

Main researcher and contact details: Khym France

Email: [Khym.France@stmarys.ac.uk](mailto:Khym.France@stmarys.ac.uk)

#### Research Project Details:

This information sheet has been designed in order to provide you with valuable information regarding a study that will involve testing the validity and reliability of a wearable accelerometer. You are being provided with this information, as it is believed you would be a suitable participant for this study.

When programming an athlete as a Strength and Conditioning coach, variables over the years have heavily relied on the volume and intensity of the session in order to determine its success. Recently acceleration data has received worthy attention due to the new analysis it can provide coaches regarding speed of execution of the movement but also fatigue of their athletes under load. The aim of this research study is to analyse the effectiveness of a wearable accelerometer by comparing it to a gold standard Kistler Force Plate in order to measure acceleration and both average power and peak power during the Squat and Counter Movement Jump.

#### Participation Details:

As you meet the inclusion criteria (aged over 18 years old, male or female, you have a training background of at least 2 years, you actively participate in physical activity 3 times per week and are currently free from injuries and have not been subject to any fracture, sprain or surgery to the lower limb in the last 24 months) you have been invited to take part in this research. However by receiving this information this does not automatically mean that you must participate. If you decide to take part in this research you also have the opportunity to withdraw at any point.

What will be required?

If you decide to take part you will be required to attend two compulsory sessions of approximately 30 minutes where data collection will last no more than 15 minutes each. The familiarisation session will be provided at the start of session 1 and will involve the collection of basic anthropometric details from you (height, weight, age) and then you will be provided with a practical demonstration and description of the two exercises you will be required to complete for data collection (squat and countermovement jump). During each session a 10 minute warm up will be provided for you which must be completed before data collection commences, you will then be asked to perform 3 repetitions of each exercise (body weight only) whilst standing on a force plate and wearing an accelerometer in the form of a band attached to the wrist.

Risks:

As with any physical activity there is a minimal risk of injury occurring however you will be appropriately warmed up for the session and will be familiarised with the correct technique for both exercises. You will also be provided with appropriate rest between repetitions and exercises. It is asked that if you agree to take part in this research that you refrain from strenuous activity at least 48 hours prior to testing.

Data Collected and Confidentiality:

All information collected during both the familiarisation and data collection sessions will be kept secure and confidential at all times and the data will be coded to ensure participants identity is not revealed.

If you require any further information, please do not hesitate to get in contact with me.

Khym France

Mobile telephone: 07966473484

**YOU WILL BE GIVEN A COPY OF THIS FORM TO KEEP  
TOGETHER WITH A COPY OF YOUR CONSENT FORM**

## Appendix C

### Consent Form Copy



St Mary's  
University  
Twickenham  
London

Name of Participant: \_\_\_\_\_

Title of the project: The validity and reliability of a wearable accelerometer during the countermovement jump and bodyweight squat.

Main investigator and contact details:

Khym France

Email: [Khym.France@stmarys.ac.uk](mailto:Khym.France@stmarys.ac.uk)

Mobile telephone: 07966473484

Members of the research team:

1. I agree to take part in the above research. I have read the Participant Information Sheet, which is attached to this form. I understand what my role will be in this research, and all my questions have been answered to my satisfaction.
2. I understand that I am free to withdraw from the research at any time, for any reason and without prejudice.
3. I have been informed that the confidentiality of the information I provide will be safeguarded.
4. I am free to ask any questions at any time before and during the study.
5. I have been provided with a copy of this form and the Participant Information Sheet.

Data Protection: I agree to the University processing personal data which I have supplied. I agree to the processing of such data for any purposes connected with the Research Project as outlined to me.

Name of participant  
(print).....  
.....

Signed.....  
Date.....

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If you wish to withdraw from the research, please complete the form below and return to the main investigator named above.

Title of Project:  
\_\_\_\_\_  
-

**I WISH TO WITHDRAW FROM THIS STUDY**

Name: \_\_\_\_\_

Signed: \_\_\_\_\_ Date: \_\_\_\_\_  
\_\_\_\_\_



In Loving memory of

Lynne Pascoe

07 March 56 – 05 April 99

*Your Love Will Light My Way*

*Your Memory Will Ever Be With Me*

*Though Absent You Are Always Near*

*Still Loved, Still Missed, Still Very Dear*